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MIDI Violin:

A digital music input device
for nonprofessional violin family instruments' players

By **Henry Hun Tao**

A Thesis submitted to the Faculty of the
College of Imaging Arts and Sciences
for the degree of
Master of Fine Arts, Industrial Design
Rochester Institute of Technology

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Master of Fine Arts Degree
Industrial Design
School of Design
College of Imaging Arts and Sciences
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Abstract

Today, making and composing music has become much easier, with dozens of DAW (Digital Audio Workstation) programs on the market that are very easy to learn and to use. These types of programs use the MIDI (Musical Instrument Digital Interface) system, which can easily simulate every sound in a home computer, and it offers everything a musician would need in the professional studio on a home computer screen. Currently, the piano keyboard-style MIDI input surface is the leading product on the market, but there has yet to be a violin-style MIDI device produced. This is because in order to simulate the violin's sounds, many different signals are required for the computer, and it is simply impossible to achieve with a keyboard-style MIDI input surface. Through my research, I found out that DAW programs and MIDI products are still unable to achieve two things:

1. Allow the user to play with delicate vibrato.
2. Reflect the violin bow techniques into the DAW programs, which is also the most important part of violin playing.

My thesis focuses on solving these two major problems to allow users to play with delicate vibrato and reflect the violin bow techniques into the DAW programs. I also want my design to reduce the difficulty of playing real string instruments, which is why I worked to design a MIDI input surface for the violin family of instruments.

Background

Making and composing music has become easier than in the past. In the past, if someone wanted to make their own music, they had to record their sounds with instruments in a million-dollar professional studio. They also had to hire a handful of workers and assistants to help connect hundreds of wires between very expensive devices and the mixing station. Basically, it takes years of professional training to accomplish these tasks and requires a lot of money. However, nowadays we have dozens of DAW programs on the market that are very easy to learn and to use. It is possible to start up a personal studio at home on a very low budget. These kinds of programs use the MIDI system, which can easily simulate every sound in a computer, and it has everything a musician needs in the professional studio right on the computer. Thus, by spending less than a few thousand dollars, DAW programs can function just like having a million-dollar professional music studio at home. Making music is no longer limited to the professionals, since everyone need spend only a little time and money to build one's own studio, and the quality is so high that even professional musicians like to use these kinds of DAW programs because they can save money and time.



About MIDI

MIDI is a way to input music from analog to the digital world. MIDI has a lot of advantages. First, if a musician record their sounds and imports them into computer programs, the sound tracks are very difficult to change and edit. But if they use the MIDI signal to input music onto their computer, they can easily change and edit everything there. Second, a musician can change their track to any sound in the program's sound bank¹. Most of the DAW program companies hired famous musicians and used expensive instruments and high-quality professional recording studios to record sound samples to build their MIDI sound bank. Thus, a musician can have very good sound quality just like the professional musicians who have recorded their music in a high-end studio², and this is why I personally chose to use MIDI for my design.



¹ "MIDI", Wikipedia: The Free Encyclopedia. Wikipedia Foundation, Inc. 20 October 2014. Web. <<http://en.wikipedia.org/wiki/MIDI>>

² Rothstein, Joseph. "MIDI: A Comprehensive Introduction". Madison, Wis.: A-R Editions, 1992.

Problems

1.MIDI

Using MIDI, a user can easily simulate the sounds of real instrument on their computer. But not every instrument can be simulated well in the MIDI system. Some classical music instruments, such as string instruments, cannot be simulated as realistically as they should be. Their variety of sounds is challenging to simulate in a computer. And it is also hard to have a high-quality acoustic recording room at home to record tracks and use it in DAW programs. This is why many are disappointed when they try to compose classical music such as movie soundtracks or orchestral pieces in DAW programs. The keyboard-style MIDI input instruments do not have enough input signal to perfectly simulate the string instrument's sound¹. And recording classical instruments usually requires special recording studios that are larger and more expensive than the studios used to record the pop music. Actually, there are only a few classical recording studios left in some big cities because the classical music market has become less popular. So it is almost impossible to rent a studio to record classical music for personal purpose.

1. Amanda Ghassaei, "What is MIDI?", instructables, 2012, <http://www.instructables.com/id/What-is-MIDI/?ALLSTEPS>

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2.DAW Programs

These days, the DAW programs we use try to record every different type of string sound, so users can find many detailed files in the strings' sound bank. If a user wants to input a classical string piece on their computer, maybe the violin solo part would require the use of more than five tracks to build this string piece, because the violin changes its sound in every bar. That being said, a user may not be able to achieve a desirable effect, because when all the sounds are coming from different files, it usually ends up sounding like five different violins trying to play like one. Even if they hired proficient musicians utilizing great violins to record the sounds, these sounds still cannot achieve the standards of real instruments.



3.MIDI Input Surface

However, while creating a home studio has become much easier than before, learning to play music instruments is still a significant commitment. A lot of amateur music players give up when they have a hard time learning instruments. This is also a problem I want to solve; I want to try to simplify the music input surface. Even if everyone has had some experience in learning one or more instruments, not everyone learned to play the piano. But, right now the piano keyboard-style MIDI input surface is still the leading product on the market. Some people have to learn how to play the piano before they start to use the DAW programs, or they will have a hard time inputting their music, and this is an inconvenience for those people who prefer using other instruments. Moreover, the piano keyboard MIDI surface also has some problems. While it can easily input the sounds of percussive instruments such as drums and piano or synthesizers etc., the keyboard MIDI device lacks a signal input for an instrument that has a variety of sounds. This is why we can see some special products such as the wing MIDI instruments and guitar MIDI instruments and drum pad, which allow people who want to create music in a more comfortable way to input their own music.



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4.String Instruments

String instruments like violin, viola, cello, and double bass are usually the main characters in an orchestra and in a symphony. String instruments are very popular because of their elegance and variety of sounds. We almost can say we cannot play classical music without string instruments. This is why when people are choosing a musical instrument to learn, violin is a popular choice. However, the violin's variety of sound is difficult to simulate in the MIDI world. Instruments like piano or drums have very simple sounds, where users only need to control velocity, and consider whether or not to use the pedal, as only two different signals can simulate every possibility of a piano's sounds. But with the violin, a bow is required to play the instrument. How the user controls the bow determines how sounds are produced. In a same pitch, using the bow or not, which part of the bow is being used, and what is the speed at which the bow is being used, the tension, and the way the user is using the bow can all affect and change the sound. On top of that, using vibrato with the left hand or not can also change the expression of the music. We need so many different signals to tell the computer how to simulate the violin's sounds, and it is impossible to do this when using the keyboard-style MIDI input surface.



Outcome

DAW programs not only allow amateurs to more easily start to play and compose their music, they also provide a convenient and cheap working surface for professionals. The professional musician would be using the string MIDI file only for their music demos, because it still cannot offer a professional sound when compared to real production. But as for the amateur players, the DAW programs might be the only recourse they have. As aforementioned, building a home recording studio for string instruments is still a proposition that most people cannot afford. Portable recording studio products that are currently on the market also do not provide the desired quality. To provide a greater quality sound to the amateur music player, I believe making a MIDI input surface that can simulate the string instruments sound is much easier and more low-cost than creating a new portable record system. It may also solve the problem of string instruments being too difficult for unpracticed people. My goal is to create a surface that can let inexperienced people play and input the violin's sound with minimal practice, and I believe that it can improve the quality of the amateur music-making industry, where people who enjoy making classical music or movie soundtracks at home can easily gain access to create better quality demos.

Goals

My goal is to design a MIDI input surface for the violin family of instruments. My target customers are the amateur musicians who prefer to use a violin-style MIDI device or someone who is trying to perfectly simulate string sounds in a MIDI way. I also want my design to reduce the difficulty of playing the real string instruments. I hope people can use my device with only a little practice, but I also hope that it will also allow someone who already knows how to play violin become familiar with the device easily.

Benchmarking (Existing Products Research)

Zeta Synthony II / String Port



The Zeta Synthony II¹ is an old product, with which users have to use the sound pickups and connect to a machine that then converts the analog signal into digital MIDI information. This MIDI information allows the machine to create sounds or send digital information to other MIDI devices, including the ability to access computer software programs such as music notation and publishing programs. These kinds of devices are no longer being produced because of their inconvenient size and hefty price, and the machines only work with their own brand's electronic violin.

¹ Zeta Music Systems, Inc. "SYNTHONY II MIDI CONTROLLER User Manual". <<http://dl.owneriq.net/fb77c27f-0ac4-41a6-8d8e-490cddbbaad68.pdf>>

O-Bow

The O-Bow¹ is a concept instrument developed by Dylan Menzies. It uses optical sensors to track the movement of a real violin bow across a groove in a piece of metal. The sensor detects the bow's angle and speed to drive the production of digital music in a connected computer. Notes are created using a separate keyboard. The concept is to try to make it easier to play than a real violin because the musician does not have to moderate the downward pressure of the bow onto the string—one of the trickiest elements of playing a violin. Many different sound effects can be created and manipulated, while rotating the bow also creates a vibrato effect.

My concept is also to try to separate the left-hand and right-hand movement, but this instrument requires the elision of pressure on the bow, which I think is actually the most important part of playing violin to create dynamic sounds, and using a keyboard simply cannot simulate the vibrato skill played by the left hand.



1 Menzies, D. (2013). The O-Bow. [Blog] Dylan Menzies. Available at: <http://www.tech.dmu.ac.uk/~dylan/z/dylan/project/obow/index.html> (accessed Oct 5, 2014).

Continuum Fingerboard

The Continuum Fingerboard¹ is a device that allows musicians to use a keyboard to produce continuous pitch similar to playing on a string. The engineering concept behind it inspired me to perfect my idea.



¹ Haken, Lippold. "Continuum Fingerboard Overview". Haken Audio. <http://www.hakenaudio.com/Continuum/hakenaudiooverview.html> (accessed May 23, 2013)

ROLI Seaboard

The ROLI Seaboard¹ is a new style keyboard from the United Kingdom, and does something very similar to what I want to achieve with my device. However, this device is very expensive and was designed for a keyboard player. On the other hand, the ROLI keyboard has a disruptive platform sensor under its soft surface, so users can achieve something like the vibrato movement on this keyboard. This is why I also wanted to add some soft elements into my device.



¹ ROLI Ltd. "ROLI Seaboard". ROLI.com. <https://www.rol.com/seaboard/> (accessed April 20, 2013)

YouRock Guitar

The YouRock Guitar¹ digital guitar is perhaps the only successful string MIDI device currently on the market. It not only can simulate the feeling of playing a real guitar but also has multiple functions, including working as a game controller. The usage of this device is very close to a real guitar, where each left-hand position on the guitar is converted into keys, and the right-hand movement can be detected through metal strings.



¹ Inspired Instruments, Inc. "YRG Gen2". [yourockguitar.com](http://yourockguitar.com/products/you-rock-guitar). <http://yourockguitar.com/products/you-rock-guitar> (accessed April 25, 2013)

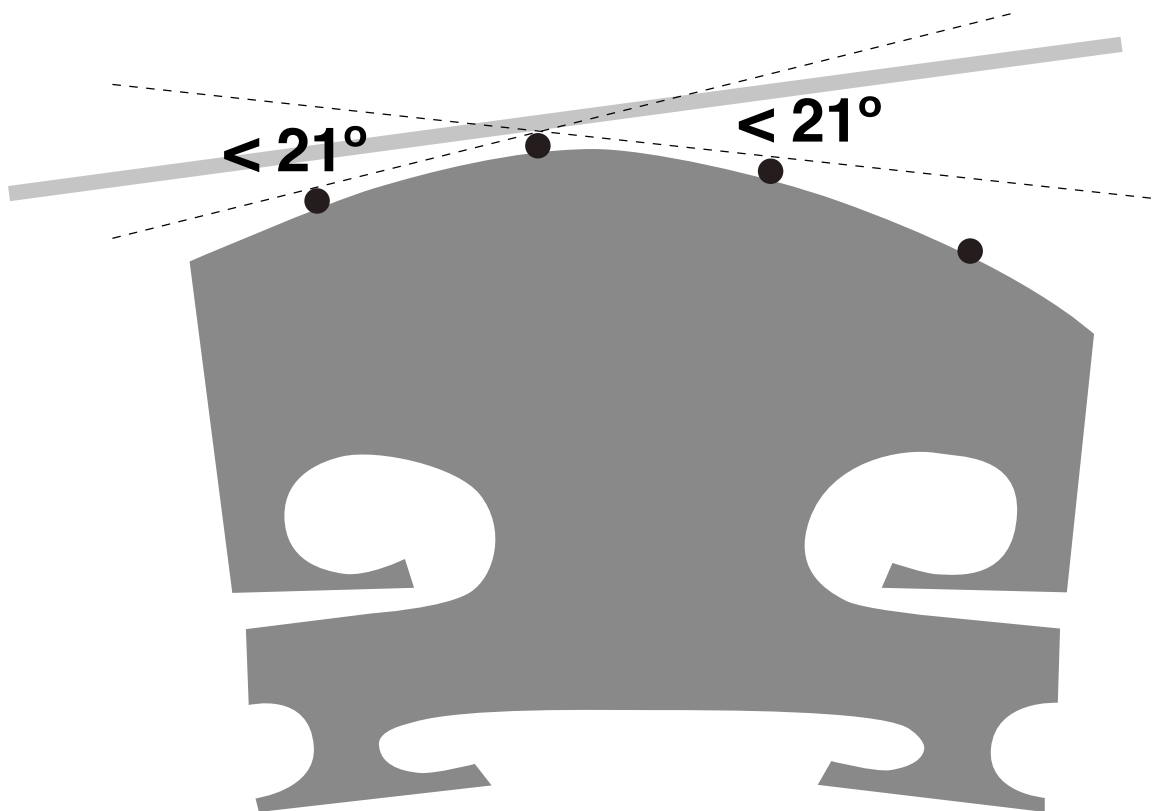
Violin Research

1. There are two major reasons that string instruments such as violin are very hard to learn:

1.1 Unlike the guitar, the violin does not have any grids and bars on its neck. Therefore, it takes an immense amount of practice to acquire muscle memory and for the musician's hands to remember the pitch position. This is a process that usually takes several years of consistent practicing.



1.2 Using the bow is the most difficult part of playing the violin and others string instruments. There are only a few degrees between one string and the next, and it takes many years to practice how to play a long bow without touching another string. Furthermore, there are lots of advanced techniques when it comes to using the bow.



2. There are some special types of sounds that are very hard to simulate in the DAW program:

2.1 Changing the sounds while the pitch continues:

For example:

Vibrato

It is a technique that is produced by shaking the pitch a little bit by wobbling a finger on the fingerboard.



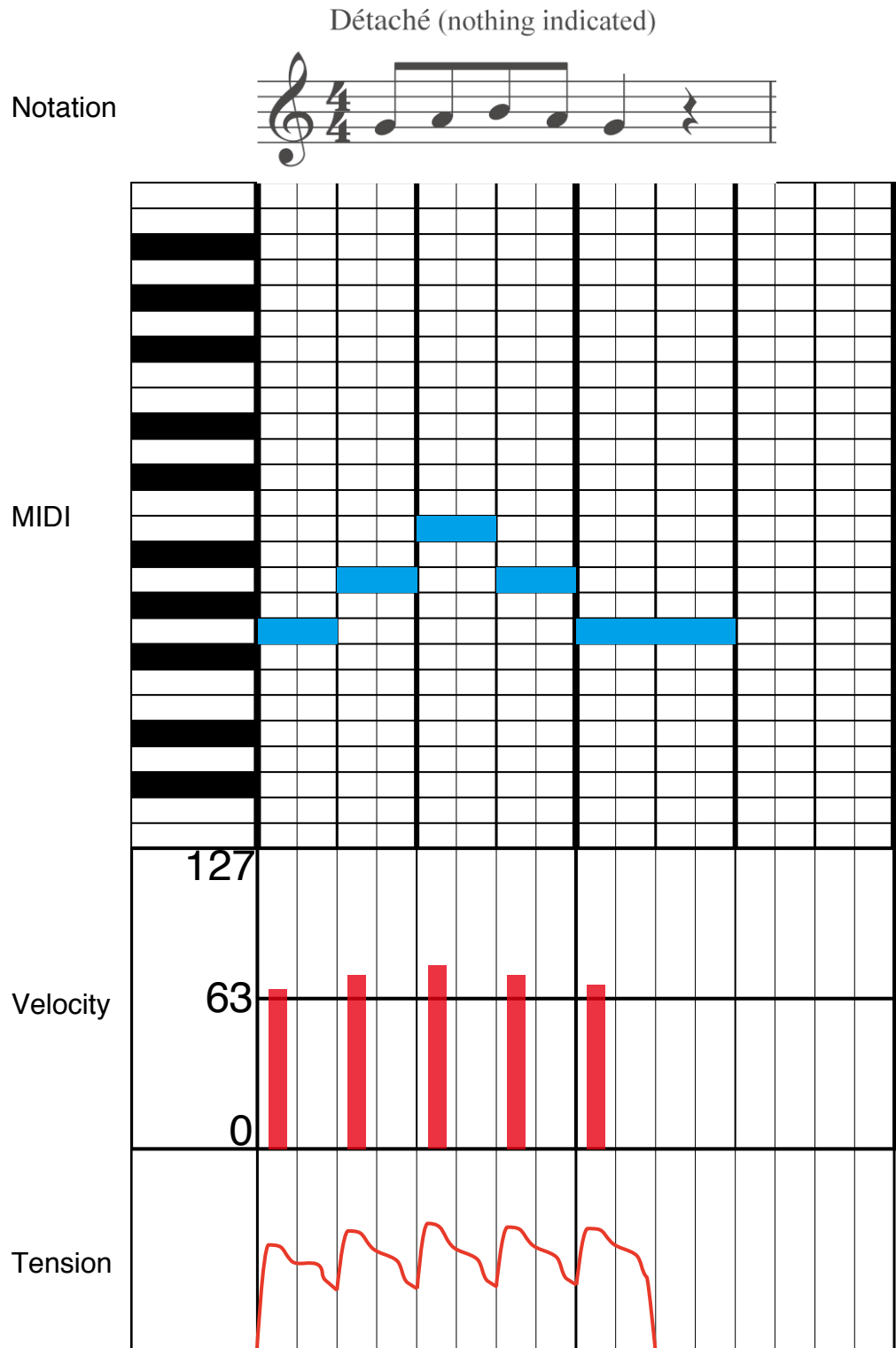
2.2 Need to use totally different sounds:

This means that every time the user changes techniques, they should create a new track and select a new sound in DAW programs.

For example:

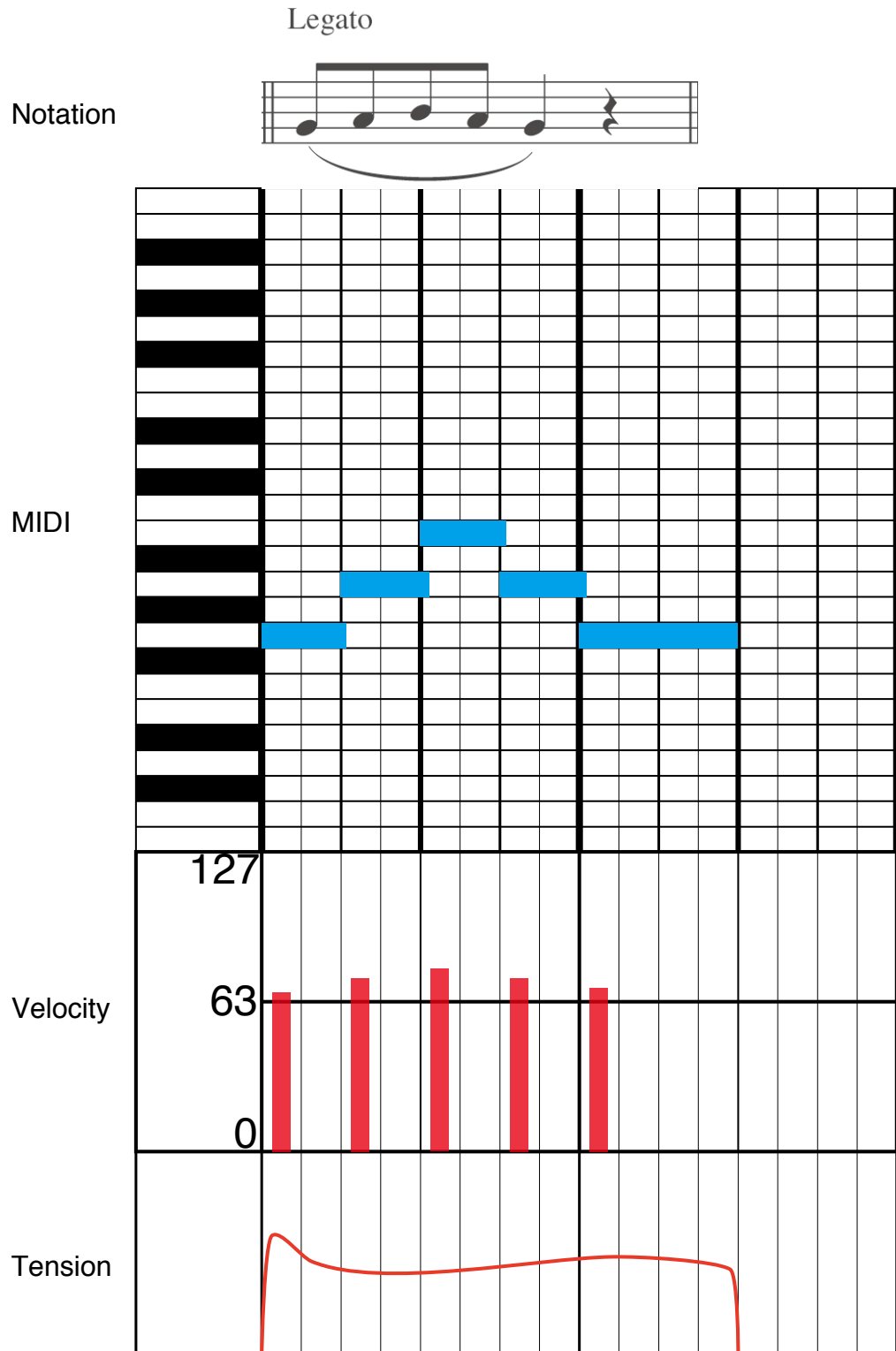
Détaché:

To bow each note separately. Nothing is indicated in the music except the notes themselves.



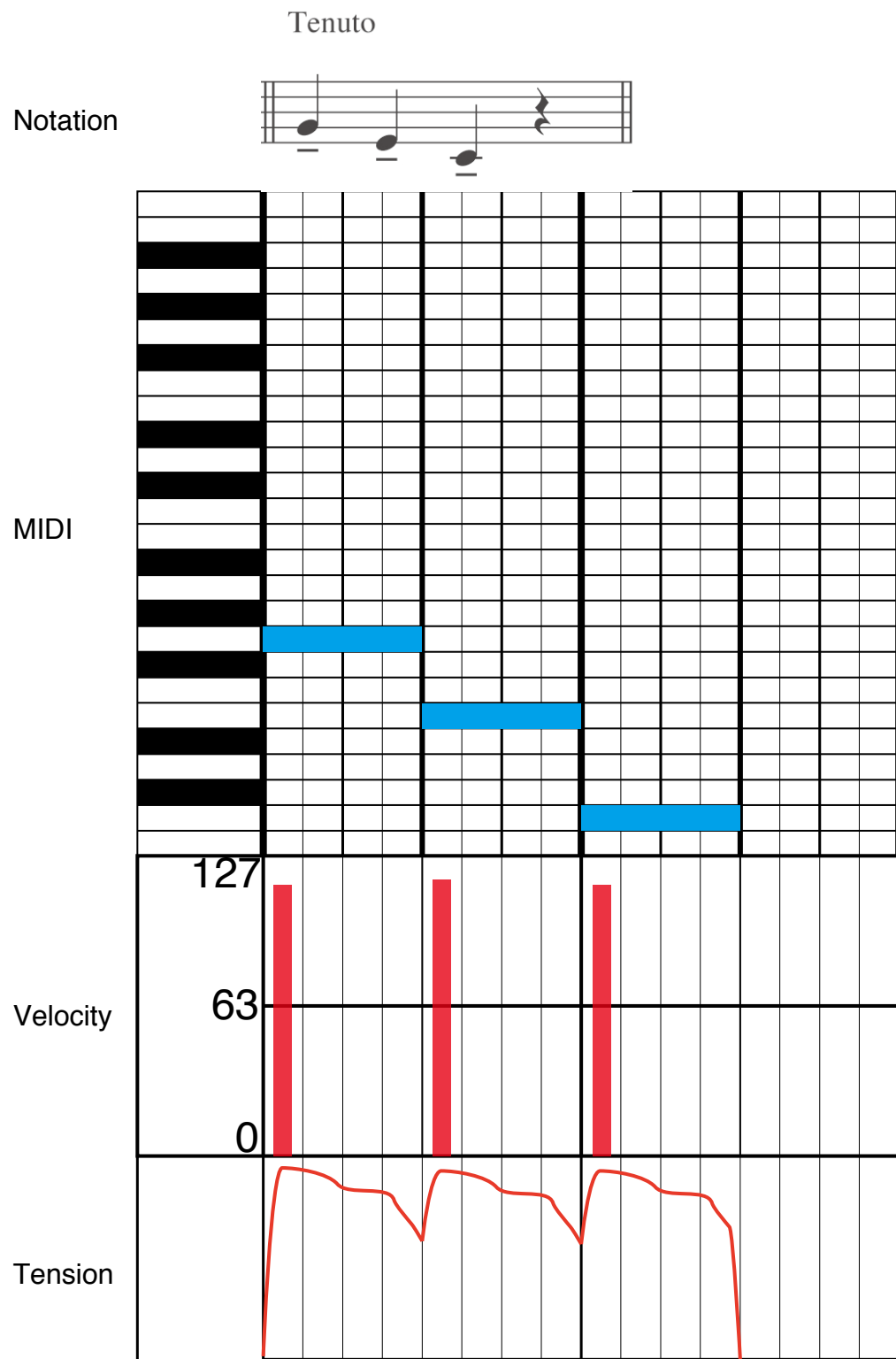
Legato:

Attached, slurred notes. When a slur is written, the notes will be grouped together as one connected phrase.



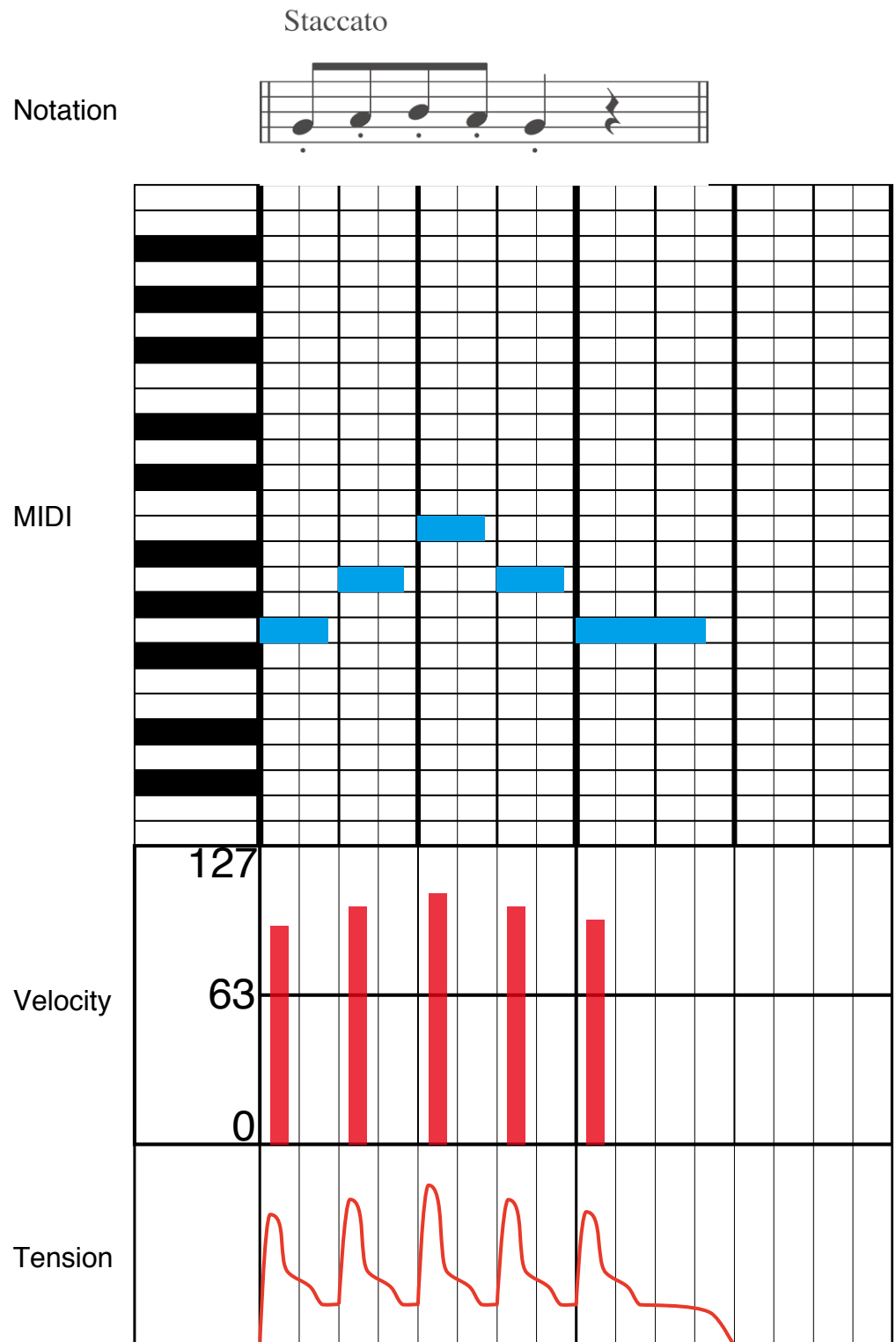
Tenuto:

Play each note for its full value. Alternating full-length bows are usually used.



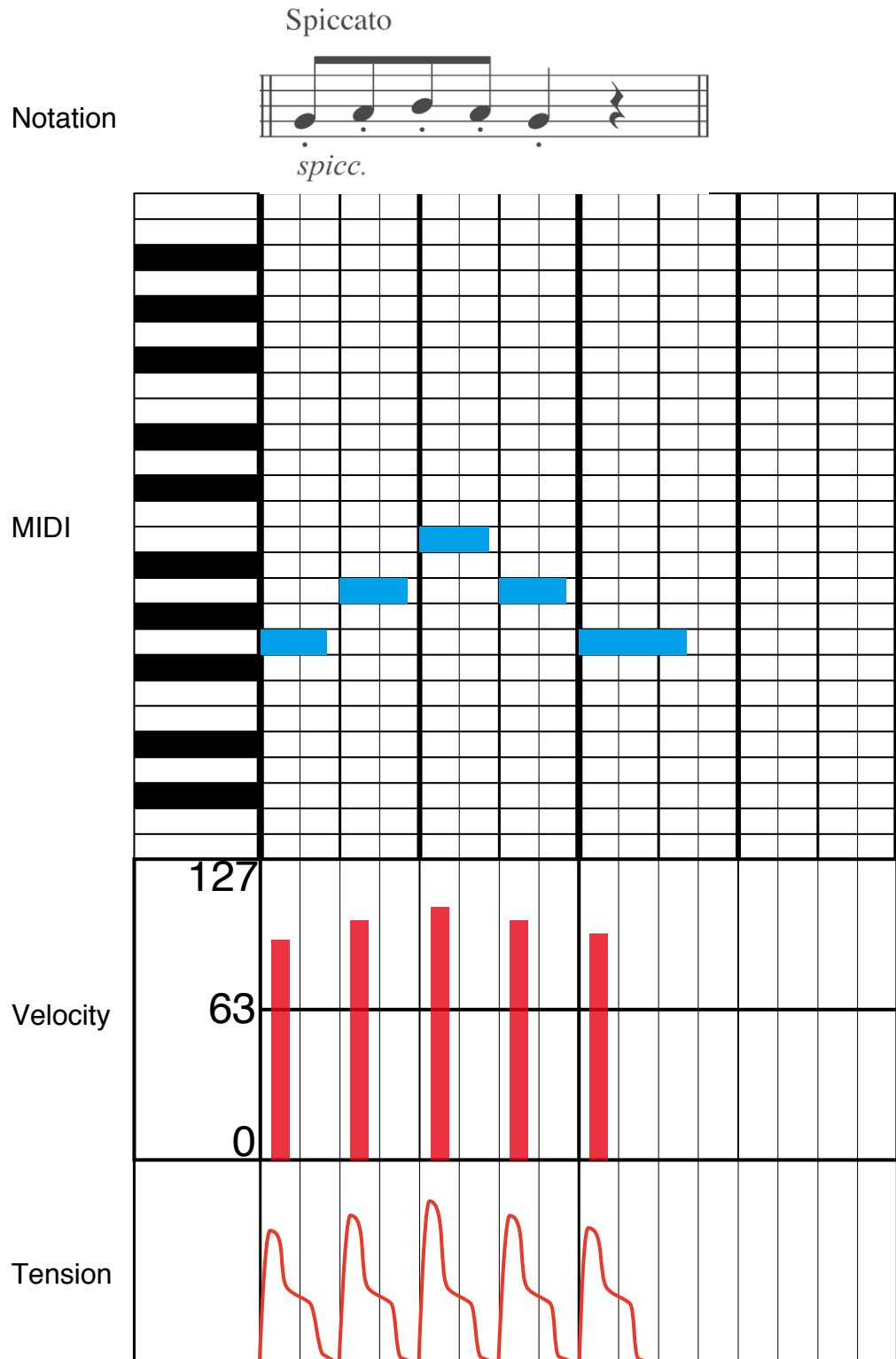
Staccato:

Short, detached notes (usually with alternating bowing).



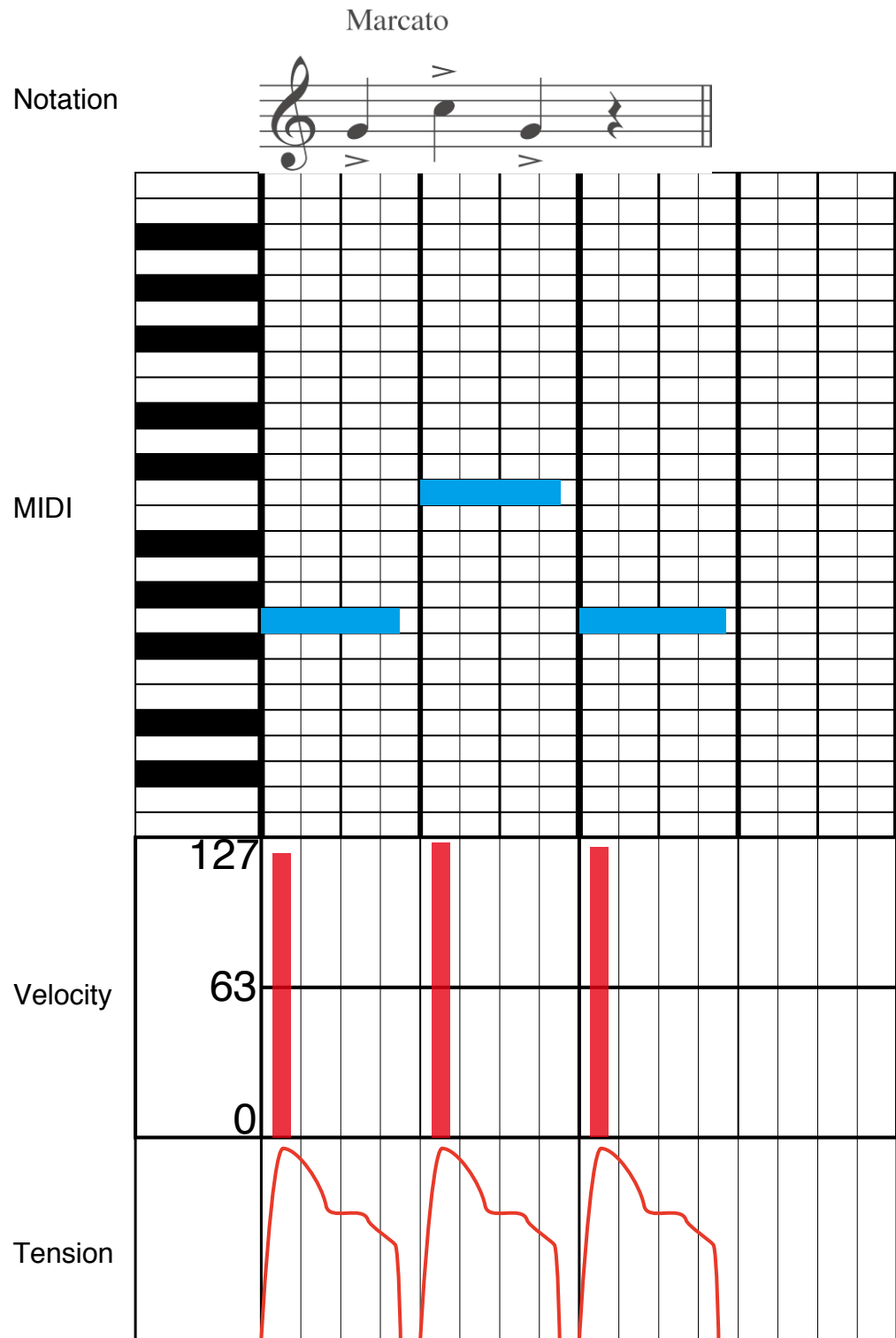
Spiccato:

The bow bounces on the strings using distinct, controlled bow strokes. This produces very short notes.



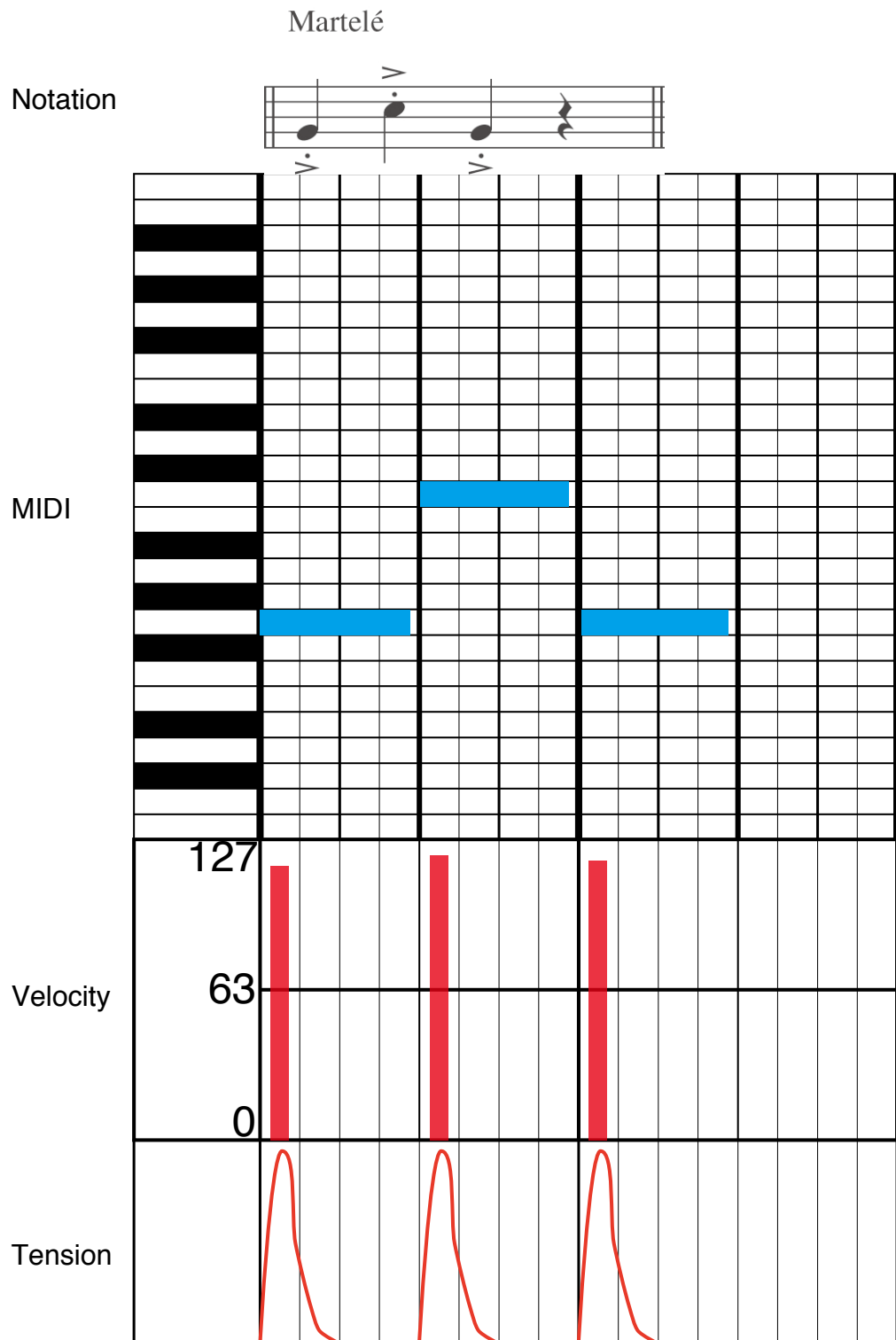
Marcato:

Long, accented, detached notes. Each stressed note is attacked separately without slurring.



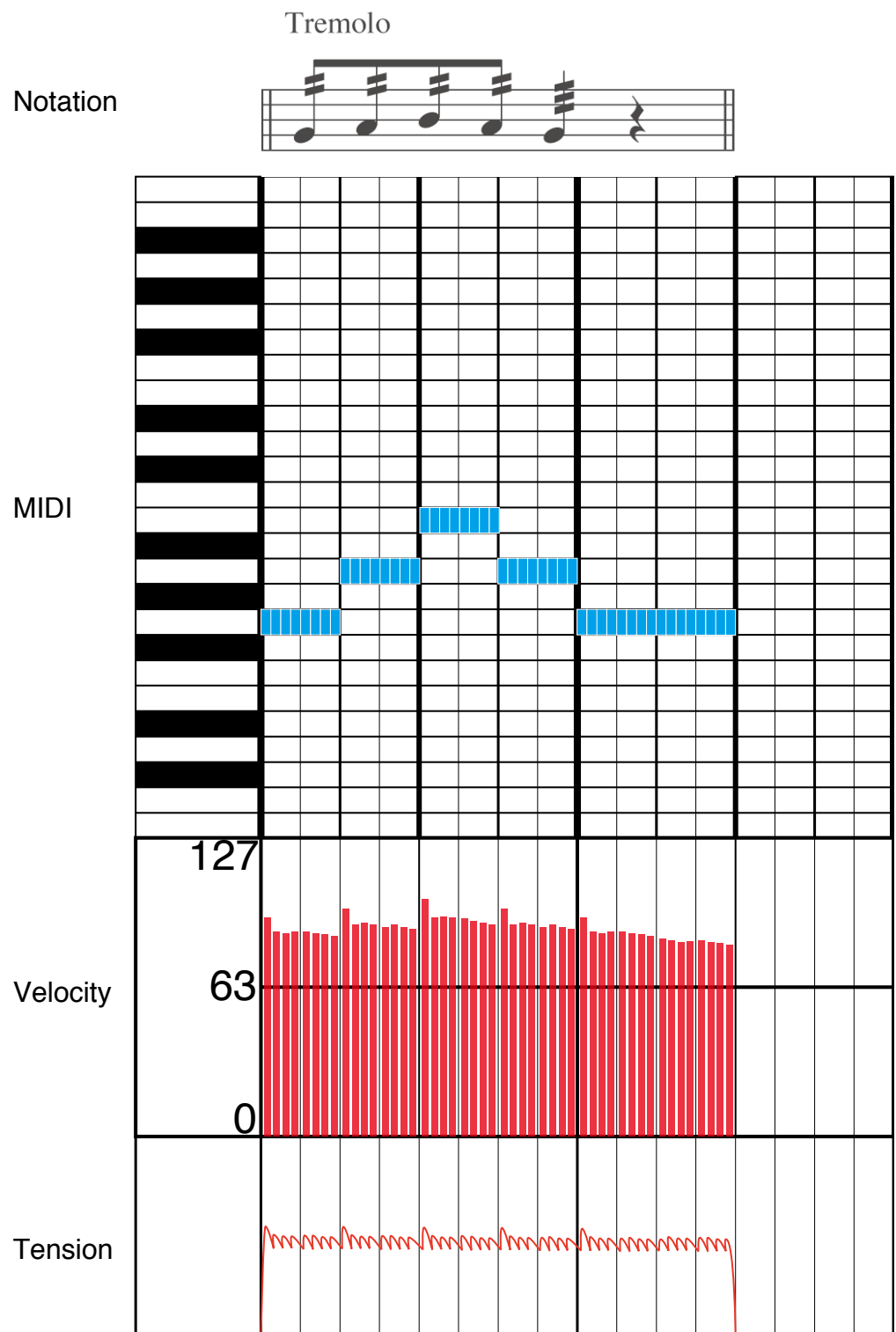
Martelé:

“Hammering” the strings. Each bow stroke is strong and accented but short (similar to marcato but with staccato notes).



Tremolo:

“Rolled” notes using fast up and down bows.



Pizzicato:

This is a technique of playing by plucking the strings with the fingers, rather than using the bow.



These are several general bowing techniques we usually use¹.

1. Starr, Eric. "General Bowing Techniques". netplaces.com. <http://www.netplaces.com/music-composition/writing-for-strings/general-bowing-techniques.htm> (accessed April 4, 2014)

Outcome

We can see that the string instrument requires the separation of the left and right hand to perform different tasks. The left hand is in charge of producing the pitch and vibrato. The right hand utilizes the bow to trigger the sounds. With that in mind, I have decided that my device should still follow this philosophy by separating the different control units to the left and the right hands.



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Violin Form Research

My target users are experienced violin players, so maintaining the same size and feeling of a real violin is very important. The violin neck size and length has to stay the same to allow the violin player to feel comfortable when using my device. Other components that need to stay true to a real violin are the fingerboard, chin rest, and the upper-right portion of the body of the violin, as those are all essential parts of the violin that are used to properly hold the instrument.



Usually, the belly of the violin is meant to help produce the sound¹, but in this case my device is totally digital, so the only concern is to make sure that the mechanical aspects fit into the body.



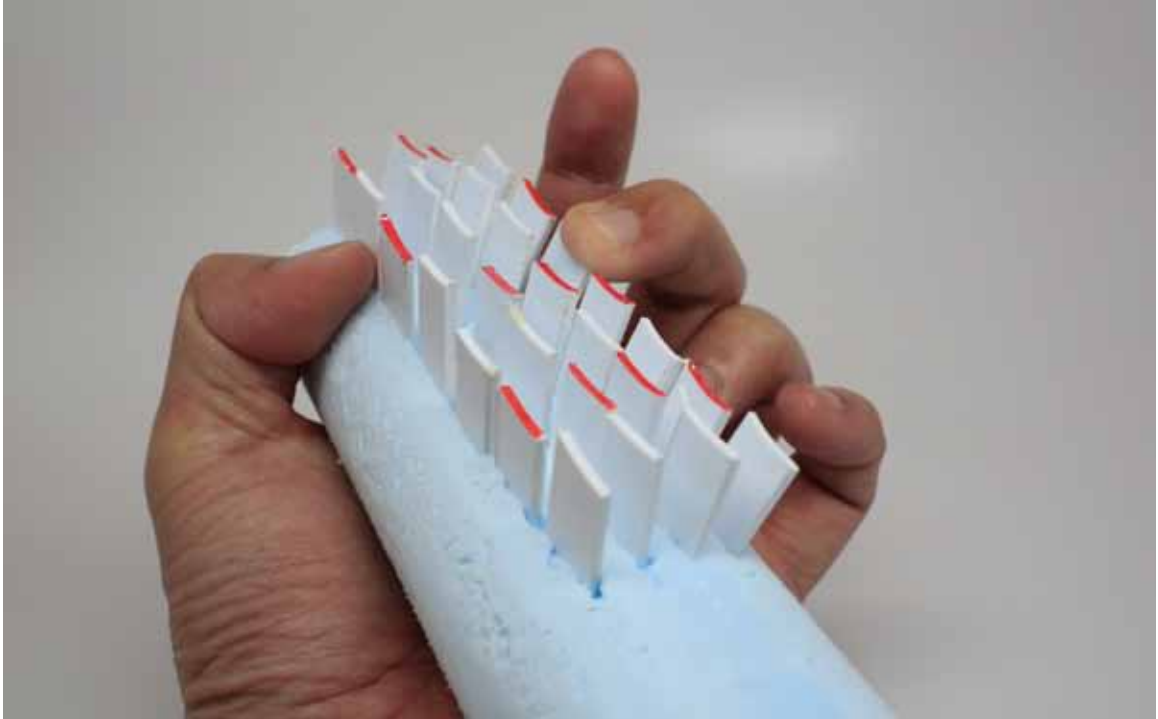
¹ Ossman, Bruce. "Violin Making: A Guide for the Amateur". East Peterburg, PA: Fox Chapel Pub., 1999.

Control Research

I did the research and made many models to think through how my device would work. I tried to combine each of the elements and see how they would work together to achieve my goal.

Left-hand control:

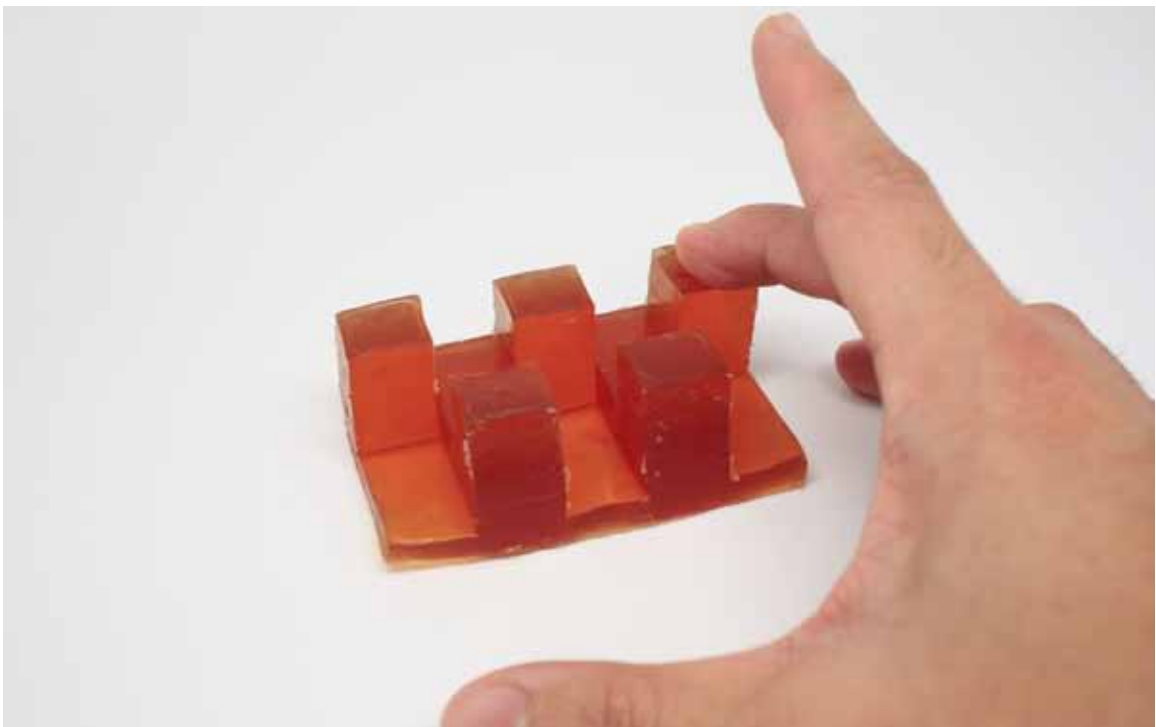
My concern was how to let the left-hand fingers not only decide the pitch, but also provide a control like the bent wheel on a MIDI keyboard, so users can play vibrato in only one hand.



Joysticks style



Soft surface



Jelly Bottom style



Rebounce bottom



Bending sensor style¹

¹ Dewa, Randitya Arika. "Developing an Invisible Guitar as Virtual Music Instrument: Modeling of a guitar string to design, build, and develop a virtual guitar system as MIDI" LAP LAMBERT Academic Publishing, 2010

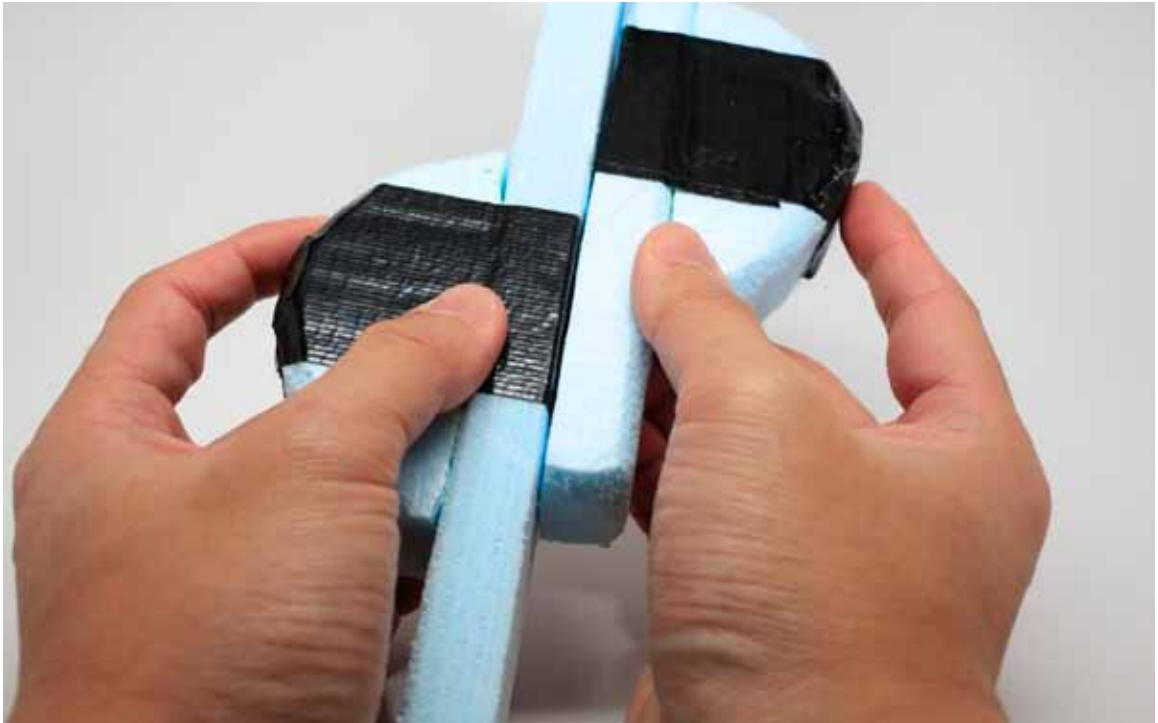
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Right-hand control:

My concern was how to trigger sounds continuously and also control speed and velocity. Different parts of position and pizzicato can trigger different type of sounds.



Accordion style



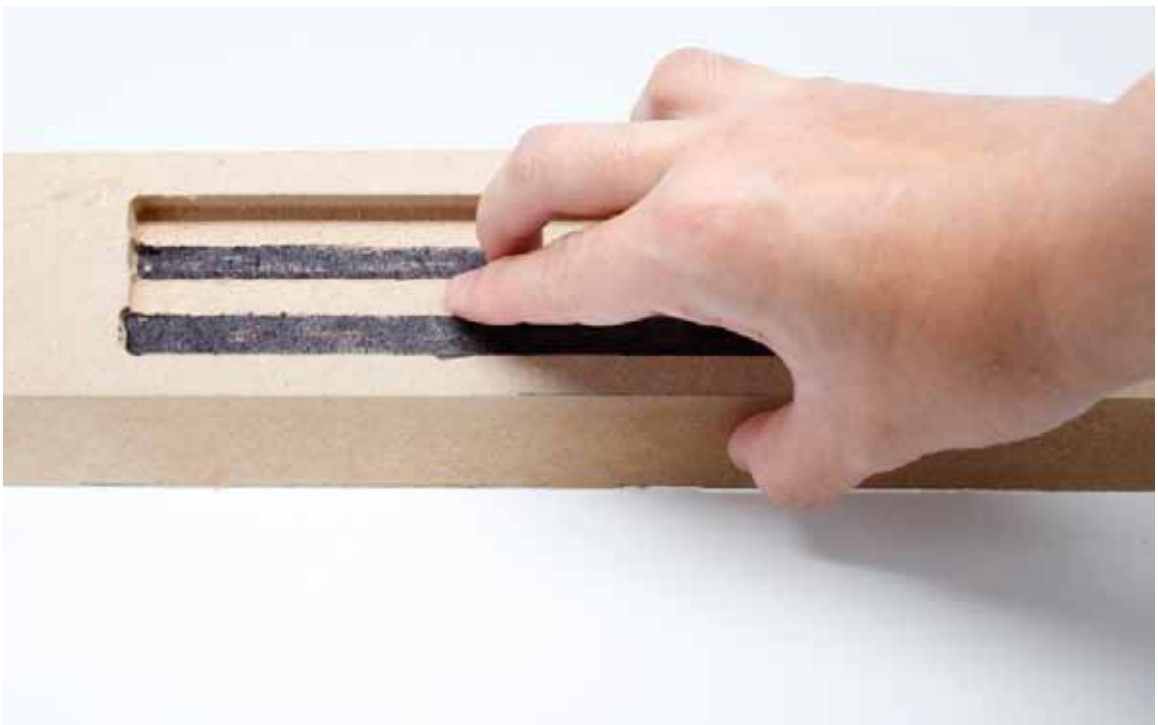
Sliding style



Rolling Wheels



String changing concept



Touch pad style

Concept mock-ups:

My initial design was to intended to eliminate using the bow altogether, and instead have the right hand slide on a touch pad to simulate the bow movement and control it. However, this introduced a completely new and different movement, and this change may confuse an experienced violinist, so I did not end up moving forward with this idea.



After a few experiments, I decided to still utilize the bow in playing my device, but instead of having the bow play on the strings, the bow plays on wheels. These wheels can sense the tension and speed from the bow, and can actually transform the flexibility and friction function from the bow to the violin body itself. Therefore, I can simplify the technology by placing the mechanical parts inside the device body and have the bow just be a normal stick.



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After testing my mock-up, I found a few problems with the shape:

It is too big and not like an instrument, so I decided to add curves to make it feel more like the original violin.



The second mock-up is a prototype for the thesis show and for use in the short demonstration movie. Through testing it, I found that this one had bad balance: the head was too heavy and this made it a little hard to use. Moreover, the design of the wheels was too narrow and small to allow the bow to function smoothly.



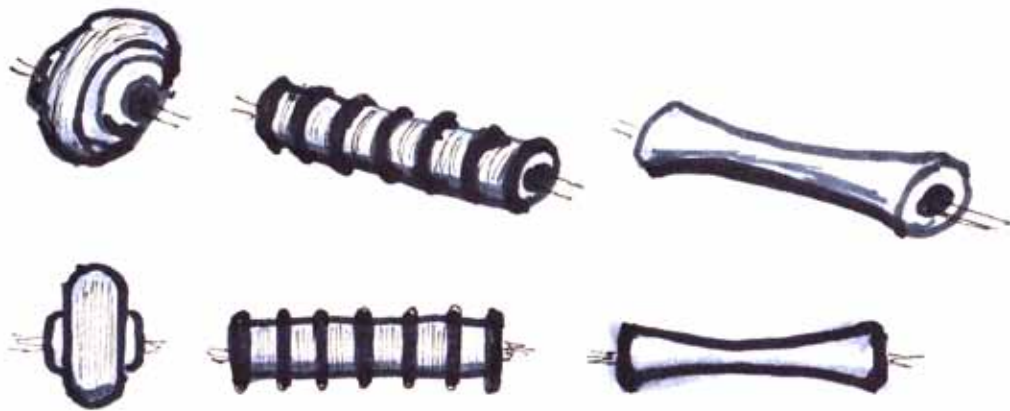
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So I redesigned it:



Sketch: Wheel improvement

I tried to fix all the problems I found and drew my new design on Solidworks as a reference to make the final prototype.





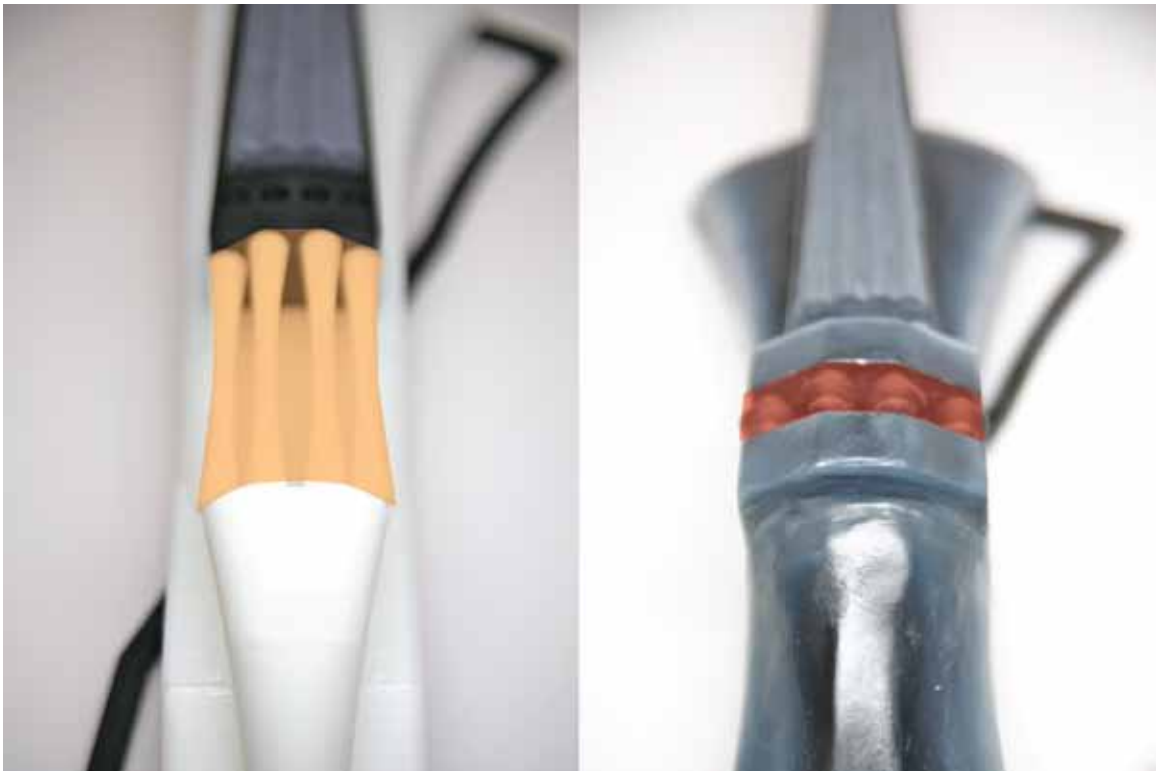
Final concept model:



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Compare:



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Design

In my research, we can see the DAW programs and MIDI products now are still unable to achieve two things:

1. Allow the user to play with delicate vibrato.
2. Reflect the bow techniques into the DAW programs, which is also the most important part of violin playing.

My design focuses on solving these two problems so it can achieve these two important goals.

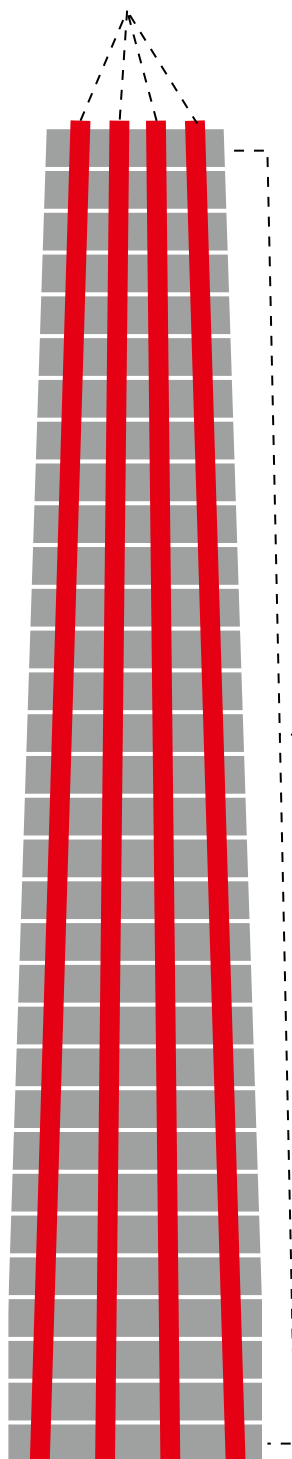


Left-hand design:

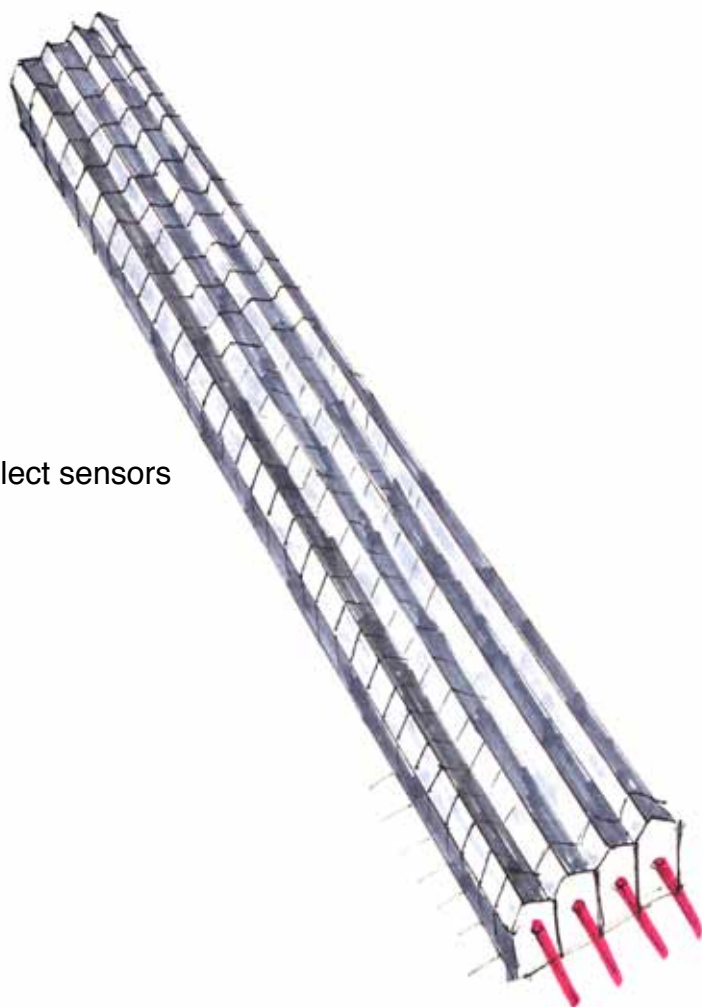
I tried to consolidate the concepts of all the great existing products and improve their ideas to fit my design. I am using soft silicon to create a string-like form and cover compact sensors inside the fingerboard. The sensor can sense the position the user touches on the fingerboard and transmit the signal to the computer, allowing the user to play the vibrato.



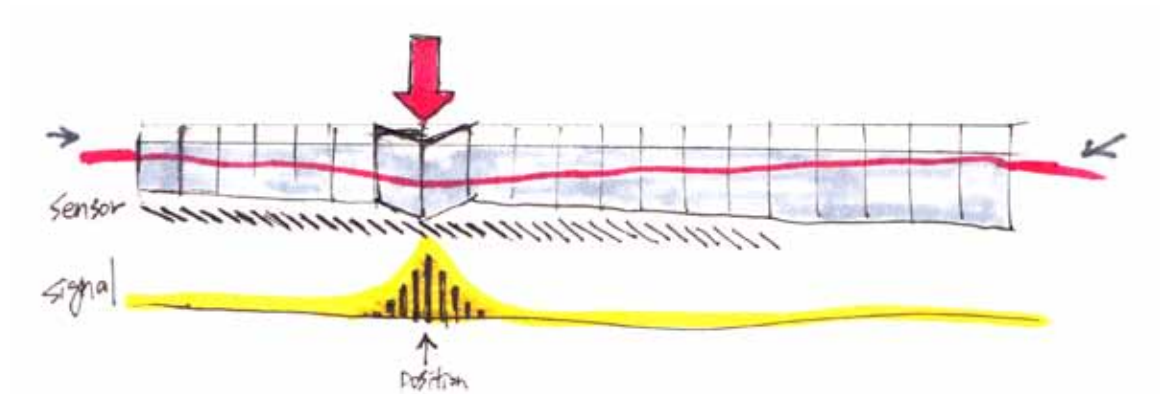
Strings select sensors



-- Pitch select sensors



Section Diagrams:



Monk, Simon. Programming Arduino: Getting Started with Sketches. New York: McGraw-Hill, 2012.

Right-hand design:

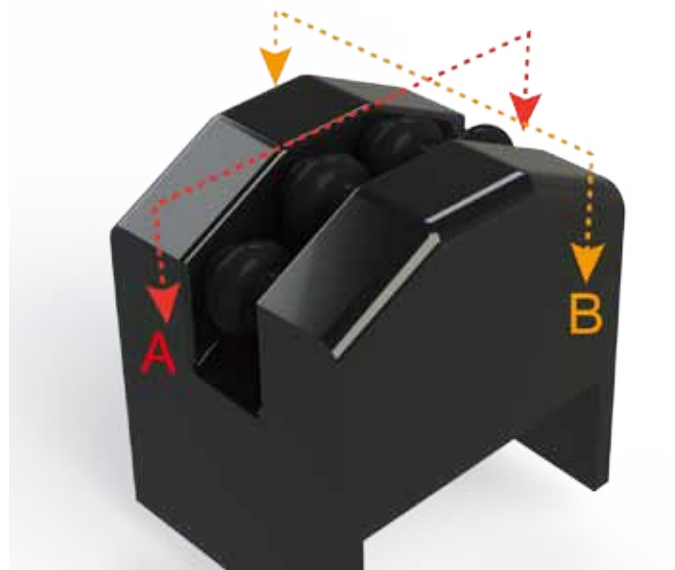
To allow the beginner violinist to use my device easily, I designed some wheels to replace the string. There are three reasons I did this:

1. My device has four different strings, so if I use an optical sensor like the O-Bow to sense the bow movement, they will interfere with each other. But if I use four wheels to sense the movement instead, only the wheel that is being touched will trigger the sound, so the device is able to know exactly what string the user is playing.

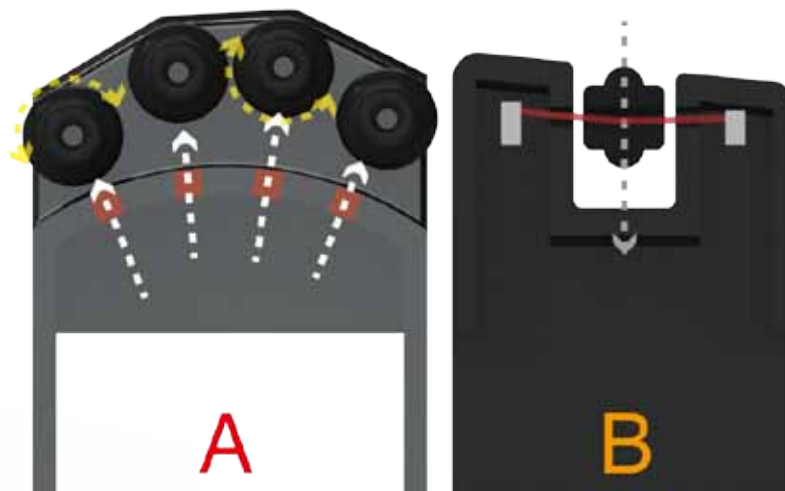


2. Each wheel not only senses the speed of how fast the user spins it, but also has a different sensor to know how hard the user touches the wheels. The speed and tension will decide what kind of sound is played.

3. The original violin features only a few degrees between string and string, so the wheels actually extend the angle between each string, making it more user-friendly for beginners.



Section:



I also designed a frame to set the chin rest on, so the user can open it when they are playing. It can be closed together so the use can save some space when they are not using it. The first position is for violin players, and if the user moves it to second position, it will become a bar that the user can hold to play the device like a cello.



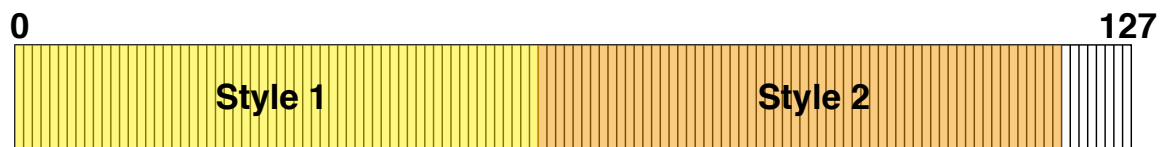
How does it work?

So far I only showed my concept design, but if I want to move forward and actually build it, how can I suggest engineers and programmers help me to make it?

How to let my design work in the DAW programs?

1. As a normal MIDI device

The normal MIDI usage can only choose one MIDI sound, but my device has to trigger different types of sounds in the same track. So there is only one possibility in this situation, which is to try to fit every sound in one track, but MIDI can only have 128 different sounds¹ in one file, making this impossible.



Violin pitch: G3 ~ G7 : 60 notes

MIDI notes limit: 0~127 (128 notes)

¹ Rothstein, Joseph. "MIDI: A Comprehensive Introduction". Madison, Wis.: A-R Editions, 1992.

2. Using a Plug-in as a set

There are so many different plug-ins for the DAW programs¹ that can extend the function, which the original DAW does not have. Some MIDI devices have their own plug-in for their special functions. My devices have to transmit so much signal that the original MIDI does not have, so I have to develop a plug-in to enable it².



¹ "Plugins Reloaded". Computer Music Journal, Issue 185, December 2012

² V.J. Manzo. "MAX/MSP/JITTER for MUSIC". Oxford University Press. November 25, 2011

Development concept:

Every sound amplitude is constituted by four parts: attack, decay, sustain, and release¹:

Attack: during which the amplitude varies gradually from zero to its maximum.

Decay: during which the amplitude decreases to a certain level.

Sustain: during which the amplitude remains roughly constant.

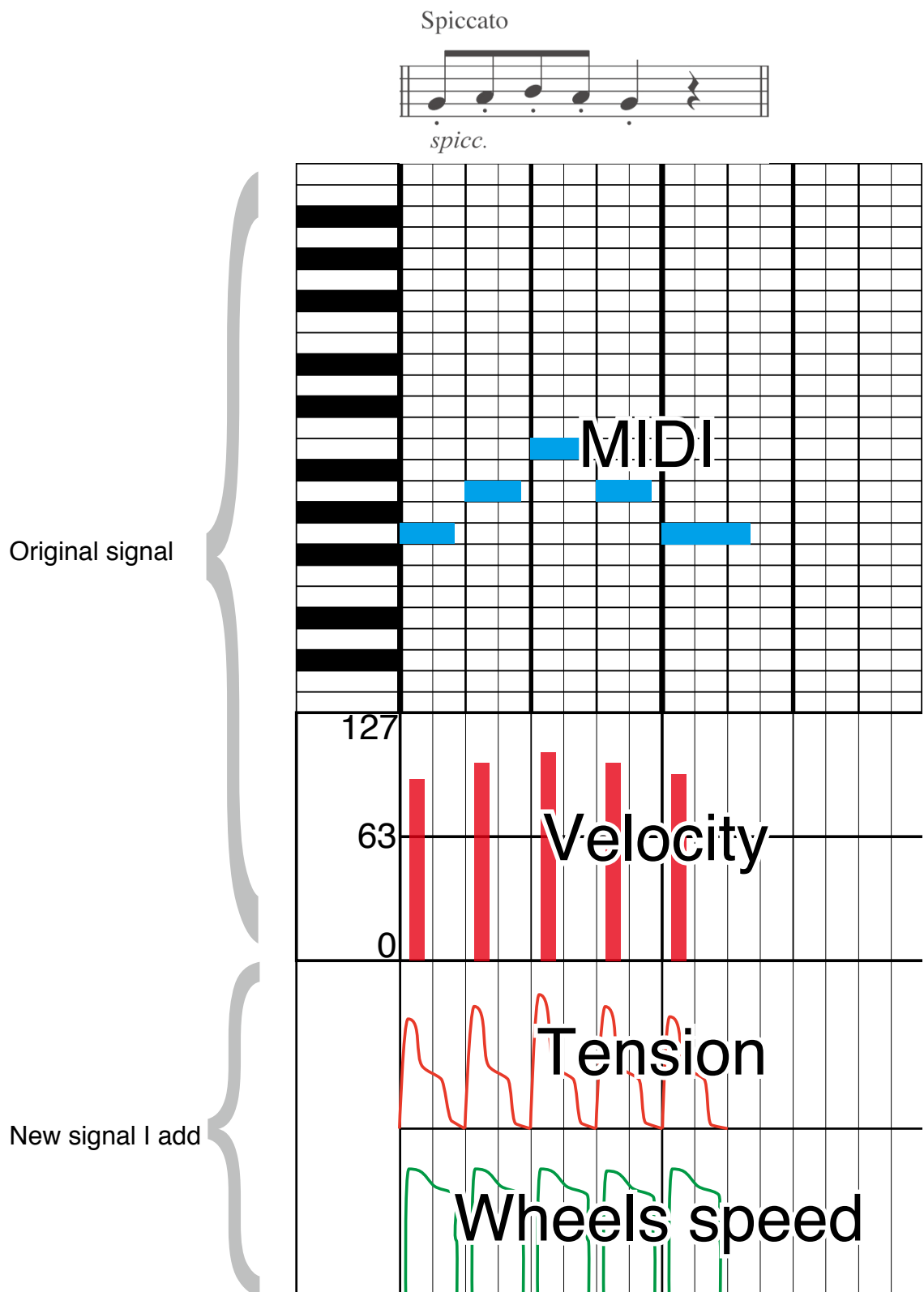
Release: during which the amplitude gradually recedes to zero.

In the normal MIDI keyboard, the speed with which a user touches the keys (velocity) decides the volume. The attack, decay, sustain, and release can be edited, and every MIDI file has its own design. By touching the key, the user can trigger the attack, and by releasing the key, the user can decide when to release the sound. It is an on/off system that the user cannot alter the wave of during the decay and sustain times. The DAW programs can only know the 0(off) and 127(on) signals in this channel. However, the violin's sound is created by moving the bow unceasingly, where the user can change the volume and style of the sound while the sound is being produced, therefore making the on/off system unsuitable for my design. As a solution, I created two new signals: the speed of the spinning wheels and the tension of the playing. These two signals will first process in my plug-in² and then transmit to the DAW programs. Not only does this provide an editable record inside the plug-in, it also perfectly simulates the sounds of the violin.

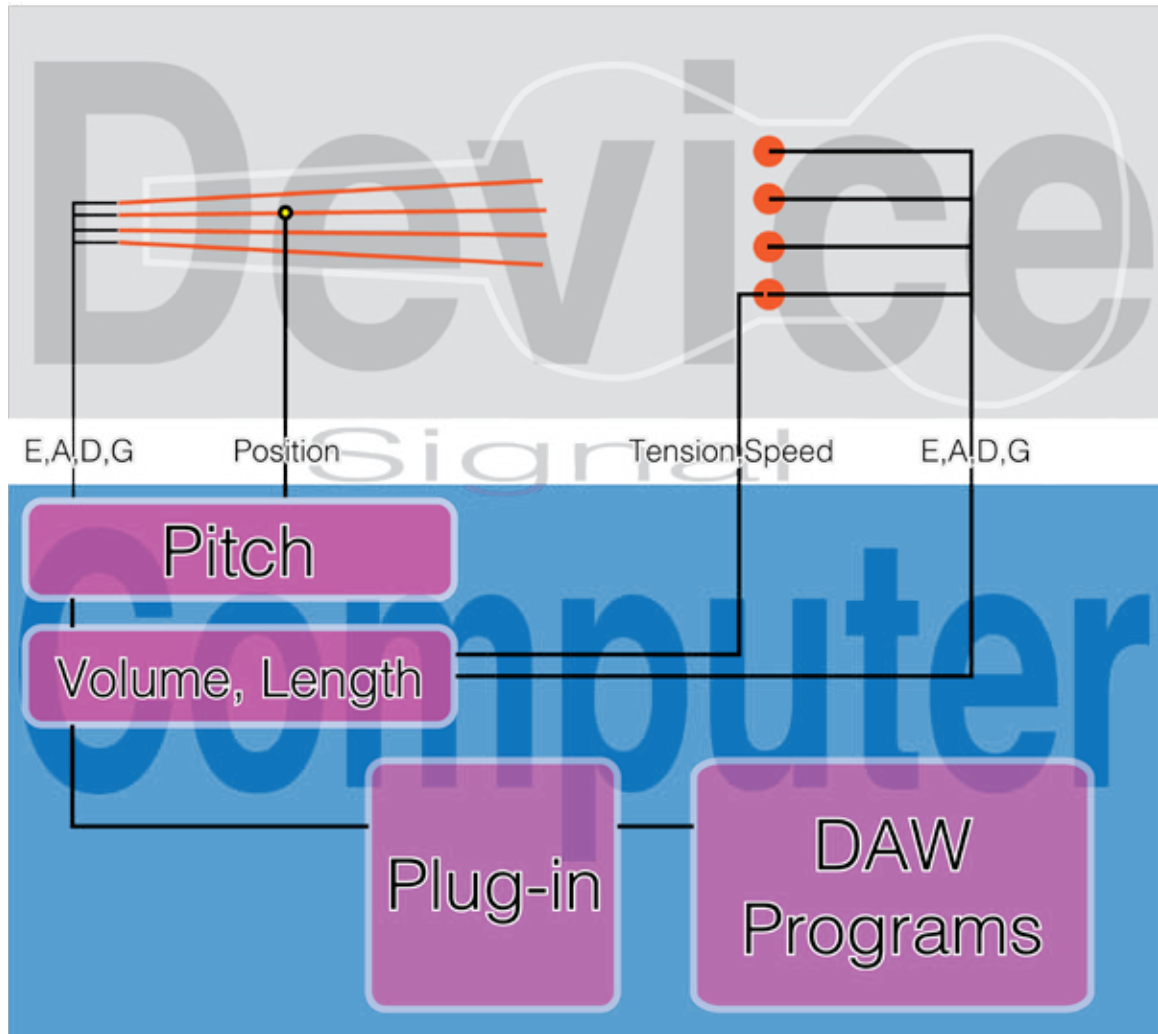
¹ Cipriana, Alessandro and Giri, Maurizio. "Electronic Music and Sound Design 1". Contemponet; Upd. June 12, 2013. p.24 p.25

² Winkler, Todd "Composing Interactive Music: Techniques and Ideas Using Max". The MIT Press. January 26, 2001

Signal Design Concept:



Working Diagrams:



Conclusion

Personally, I am a violin player and have been practicing for almost eighteen years. On top of that, I can also play the classical guitar and the piano, and my hobby is making music. I have learned how to use certain professional music-making programs such as Reason and Cubase, but almost all of these music programs require the user to use a piano-style keyboard MIDI instrument to input or edit their notes. Even though I know how to play the piano, I am not a professional musician (most professional musicians have to choose piano as their minor, so even if the piano is not their primary instrument, they still have some basic piano skills), so the keyboard instruments are really not the most comfortable and familiar for me and many other nonprofessional music lovers. This is why I wanted to pursue this thesis project and hope to solve this problem. Since computer music and the MIDI system are a totally different field for me, I spent a lot of time doing research. The design concept is based on research from my eighteen years of experience playing musical instruments, and almost one year spent learning how to use DAW programs.

I am sure that this concept can work and solve most of the problems that I have mentioned, but there are still many challenges to tackle in order to make a fully functional prototype. My design concept can perfectly simulate string sounds in a MIDI way and allow violin players to have a much more convenient means to input their music. It can also reduce the difficulty of playing real string instruments. Not only can this concept be utilized for string instruments, it can also improve the original MIDI working process to simulate better and more realistic sounds, and I hope that one day this concept may come to fruition and become a reality.

References

"MIDI", Wikipedia: The Free Encyclopedia. Wikipedia Foundation, Inc. 20 October 2014. Web. <<http://en.wikipedia.org/wiki/MIDI>>

Rothstein, Joseph. "MIDI: A Comprehensive Introduction". Madison, Wis.: A-R Editions, 1992.

Amanda Ghassaei, "What is MIDI?", instructables, 2012, <http://www.instructables.com/id/What-is-MIDI/?ALLSTEPS>

Zeta Music Systems, Inc. "SYNTHONY II MIDI CONTROLLER User Manual". <<http://dl.owneriq.net/f/fb77c27f-0ac4-41a6-8d8e-490cddbbaad68.pdf>>

Menzies, D. (2013). The O-Bow. [Blog] Dylan Menzies. Available at: <http://www.tech.dmu.ac.uk/~dylan/z/dylan/project/obow/index.html>

Haken, Lippold. "Continuum Fingerboard Overview". Haken Audio. <http://www.hakenaudio.com/Continuum/hakenaudioovervg.html>

ROLI Ltd. "ROLI Seaboard". ROLI.com. <https://www.roli.com/seaboard/> (accessed April 20, 2013)

Inspired Instruments, Inc. "YRG Gen2". yourockguitar.com. <http://yourockguitar.com/products/you-rock-guitar>

Starr, Eric. "General Bowing Techniques". netplaces.com. <http://www.netplaces.com/music-composition/writing-for-strings/general-bowing-techniques.htm>

Ossman, Bruce. "Violin Making: A Guide for the Amateur". East Peterburg, PA: Fox Chapel Pub., 1999.

Dewa, Randitya Arika. "Developing an Invisible Guitar as Virtual Music Instrument: Modeling of a guitar string to design, build, and develop a virtual guitar system as MIDI" LAP LAMBERT Academic Publishing, 2010

Hopkin, Bart. "Musical Instrument Design: Practical Information for Instrument Making". Tucson, Ariz.: See Sharp Press, 1996.

Monk, Simon. Programming Arduino: Getting Started with Sketches. New York: McGraw-Hill, 2012.

Rothstein, Joseph. "MIDI: A Comprehensive Introduction". Madison, Wis.: A-R Editions, 1992.
"Plugins Reloaded". Computer Music Journal, Issue 185, December 2012

V.J. Manzo. "MAX/MSP/JITTER for MUSIC". Oxford University Press. November 25, 2011

Cipriana, Alessandro and Giri, Maurizio. "Electronic Music and Sound Design 1". Contemponet; Upd. June 12, 2013.

Winkler, Todd "Composing Interactive Music: Techniques and Ideas Using Max". The MIT Press. January 26, 2001